The present invention pertains to a microphone that responds to structure-borne sound according to the preamble of Claim 1 or 2. Microphones of this type are known from US-PS 4 591 668 and US-PS 2 311 416. The invention also pertains to the utilization of such microphones.

State of the Art

In reproducing/recording units, the speech function is, according to the most recent state of the art, predominantly achieved with dynamic, noise-compensated microphones. This can essentially be explained by the fact that these microphones are in the meantime able to provide a superior degree of shielding from ambient noise, with the reproduction of voiced sounds also having reached a high quality with respect to the tonality and the timbre. However, this naturally requires that the handling of these microphones takes place in accordance with low-tolerance operating instructions. However, it is quite obvious that such a microphone bolder is frequently perceived to be an obstruction within the region of the mouth opening, namely because it is frequently desired or absolutely imperative for the frontal portion of the face to remain free of such implements. In light of this fact, it was repeatedly attempted to remedy this situation with a microphone that responds to structure-born sound. When using throat microphones that form part of the state of the art, it needs to be taken into consideration that microphones of this type are not provided with the ideal conditions regarding the pick-up of voiced sounds due to the location at which they are used. If one observes the quality of voiced sounds at the throat, it is easily possible to ascertain that the average portion of the sounds of higher frequencies which are generated at this location merely amount to 20% of the entire spectrum; the portion of sounds of lower frequencies, in comparison, amounts to approximately 80%. These are inferior prerequisites for a reproduction of voiced sounds with a strong presence. In addition, the physiological component in the throat also causes high noise portions, namely even at a normal speech volume. Although the primary throat sound is converted in the voice-forming portion of this organ (glottis) to such a degree that a voice which can be differentiated with respect to the tone can be achieved with the aid of a resonant conversion, the timbre is still rudimentary because the final modeling of the voice takes place in another speech-forming organs (tongue, lips, lower jaw, soft palate, teeth, etc.). Due to the individual characteristics of such organs, this leads to voiced sounds that can be differentiated. Modern microphones which respond to structure-borne sound are unable to provide a satisfactory solution. This is the reason why the use of lip microphones still appears justified.

In light of these circumstances, DE-PS 22 30 637 proposes to pick up the voiced sounds in a different fashion; the location at which the voiced sounds are picked up is displaced into the vicinity of the jaw joint by utilizing a voluminous dynamic gradient microphone. This placement

is based on the notion that voiced sounds should be picked up at the location at which they are modeled as best as possible with respect to structure-borne sound. Although an improved quality of the timbre of the voiced sounds to be reproduced can be achieved in this fashion, the acceptance of the microphone proposed for this purpose could not be realized to the desired degree because of the voluminous design of the microphone and the quality expected by the user, which still has not been attained.

The structure-borne sound microphone disclosed in the initially cited US-PS 4 591 668 contains a plate as the transmitter. This plate contains an integrated piezoelectric resonator and is connected to the microphone capsule either directly or indirectly at different discrete locations. In addition, this plate contains recesses near the connecting points. These recesses are designed such that a general S-shaped band is obtained. The central portion of this band carries the resonator, with the opposite ends of the band being fixed to two diagonally opposite points of the microphone capsule. The purpose of this design consists of increasing the effective length of the thusly created diaphragm in order to reduce its self-resonant frequency. According to US-PS 2 311 416 which was also cited above, the mechanical-electrical transmitter should be realized in the form of an induction coil, and its vibratory support should be realized in the form of two parallel circular plates or disks that are clamped between flatly adjoining rings over their entire circumference. Three spoke-like arms extend from this circumferential edge to the central portion that holds the transmitter. However, these arms do not extend radially, but rather helically in order to increase the flexibility of the entire holding arrangement.

It was determined that the gap between interference signals and useful signals during the reproduction of picked-up voiced sounds is not satisfactory in all known structure-born sound microphones. As described in greater detail below, there also exist disadvantageous vibrations that could not be controlled until now and that propagate along the end faces of the plate used as the vibratory holding arrangement with a high energy that is considered disadvantageous for the microphone transmission (surface transmission), with these vibrations also impairing the transmission of voiced sounds received from the sound pick-up on the side of the body.

Objective of the Invention and Solution

Consequently, the invention is based on the objective of maximizing the gap between interference signals and useful signals during the reproduction of picked-up voiced sounds in a microphone of the aforementioned type while simultaneously eliminating sound interferences from ambient noise. According to the invention, this objective is attained with the characteristics of Claim 1 and Claim 2. Advantageous embodiments and additional developments of the invention as well as one specific utilization of the microphone according to the invention are described in secondary Claims 3-8.

The invention utilizes the fact that the above-mentioned disadvantages in the transmission of vibrations can be prevented by providing a three-point anchoring of the vibrating plate and taking into consideration the fact that the three fixing points form the corners of an equilateral triangle. It was determined that the neutralization of the previously mentioned vibrations which travel from one point to another point becomes higher if the three mounting points accurately represent an equilateral triangle.

Another advantage of the invention is the possible miniaturization of the microphone which could decisively broaden its scope of applications.

In order to better comprehend the basic aspects of the solution according to the invention and consequently its quality, a few considerations regarding the physics of transmitting vibrations in structure-borne sound microphones are provided below.

Microphones which respond to structure-borne sound and are situated within the region of the zygomatic arch (arcus zygomaticus) or within the region of the condylar process of the mandible (processus condylaris mandibulae) are able to generate a high-quality reproduction of the voiced sounds picked up at this location because this pick-up pertains to voiced sound that originate from the mouth cavity, i.e., from an environment where the voice is formed with respect to the timbre and from where the voice subsequently travels to the outer bone of the auditory canal (os tympanicum) via the auditory canal on the side of the cranium. The zygomatic arch, and, downward and adjacent, the condylar process of the mandible are situated within the region of the outer bone of the auditory canal. This pick-up point represents an optimum for microphones that respond to structure-borne sound. If this arrangement is combined with the microphone according to the invention, one attains the essential advantage of the invention, namely that an increase of the frequency response within the speech range can be detected. This increase in the frequency response causes a qualitative improvement in the reproduction such that more higher sound frequencies are preferred and the presence of the speech is significantly improved. The invention makes it possible to achieve at least the reproduction quality of a lip microphone because lower frequency tones and nasal tones of the voiced sounds are filtered out or suppressed, respectively, and the still relatively small portion of high frequency tones is maximized with respect to the voltage for the above-mentioned reasons.

The advantages of the invention have a common origin that is tightly correlated to the design of the object of the invention: the piezoelectric resonator and, in an analogous fashion, the induction element transmit only those vibrations to the amplifier which impact the plate transversely. The piezoelectric resonator is integrated into the plate that preferably consists of a metallic material, with the induction element being connected in series to this plate at a certain distance. Regarding the plate, it should be mentioned that it is parallel to a diaphragm that is situated in front of the plate on the side of the body, with the plate preferably being fixed at three

points relative to a cover that forms the ground. Consequently, vibrations which impact the microphone outside of the aforementioned plane are unable to act upon the transmitters, with an insulation that preferably consist of a silicone material that can neutralize general sound interferences.

In this context, the geometric shape of the aforementioned plate as well as the physical processes occurring in this plate and the transmitters should also be discussed: the simplest plane sources of sound are vibrating diaphragms and plates. The difference between diaphragms and plates are the same as those between a string and a rod. From a physical point of view, a diaphragm is such a thin, flat object that it has no resistance to bending; consequently, a diaphragm is only able to perform mechanical vibrations if it is tightly stretched by an external force, e.g., similar to a percussion drum. A plate, in contrast, has so much bending elasticity that it is able to perform elastic vibrations without external forces, with said bending elasticity being caused by the greater thickness of the plate in comparison to a diaphragm. In these specific observations, only transverse vibrations, which are also referred to as bending vibrations and cause the plate to vibrate, are important. A plate would, in principle, not even have to be fixed in order to exhibit the desired effects. The acoustic pattern of a plate upon which transverse vibrations act can be decisively altered by selecting a certain geometric shape of the plate as well as a predetermined number and the corresponding locations of the fixing points between the plate and the housing. Consequently, the chosen geometric shape of the plate and its fixing arrangement predominantly represent a measure for how regular the acoustic patterns actually are. The acoustic pattern can be significantly altered by manipulating these variables, i.e., the relative portions of high and low sounds can be shifted. An elevation of the relatively small portion of high sounds in a microphone that responds to structure-borne sound in combination with a regular acoustic pattern can be achieved with a plate that is preferably anchored to the body of the microphone which forms the ground at three points that are uniformly distributed over the circumference. The nodal lines of the acoustic pattern result in an acoustic pattern that is regularly trimmed to harmonics if this type of fixing the plate is chosen. In this case, one needs to take into consideration that the optimal sound communication range lies between 300-3000 Hz. In order to prevent the acoustic pattern which is formed by the transverse vibrations and which is due to the location at which the voiced sounds are picked up, still characterized by a relatively large portion of low frequency sounds, from not turning out excessively dull, e.g., such that a nasal sound would result, the excitability of the plate is increased by corresponding recesses, with said recesses being quite suitable for correcting the variables of the plate and its environment due to their variability. These variables pertain to the physical properties as well as the geometric shape of the respective plate. In addition, the "peak point" (= highest amplitude value depending on the frequency) is also influenced by the number and the corresponding locations at which the

plate is fixed to the cover of the microphone. Even the quantity and quality of the insulation mass used in the microphone have corresponding effects. These variables also highly influence the corresponding effects, namely because the desired miniaturization of the object of the invention only allows a small plate, the minimum thickness of which may, under certain circumstances, result in a disproportionate relation to the predetermined surface area.

The advantages which could only be achieved with an active sound controller that, however, has a higher space requirement and consumes additional current can now be attained in an exclusively passive fashion with the innovative design of the microphone according to the invention.

When using the object of the invention as a throat microphone, the invention makes it possible to substantially improve the degree of efficiency regarding the timbre of the transmitted voiced sounds.

Additional advantages as well as practical additional developments and uses of the object of the invention are characterized in the remaining claims.

Embodiments of the invention are described in greater detail below with reference to the figures. All elements which are not required for comprehending the invention were omitted. In all figures, identical elements are respectively identified by the same reference symbols.

Brief description of the figures

The figures show:

Figure 1, a microphone that responds to structure-borne sound;

Figure 2, a view of the microphone according to Figure 1 along the plane of section II-II which, in particular, indicates one shape of the plate;

Figure 3, a reproducing/recording unit which can be worn on the ear, and

Figure 4, a reproducing unit which can be worn on the ear.

Description of the Embodiments

Figure 1 shows a microphone that responds to structure-borne sound and consists of an outer housing 1, an amplifier 2, an insulation body 3, an intermediate ring 4 that is surrounded by the insulation body 3, a diaphragm 5 on the side of the body which, from a physical point of view, represents a plate with a pin 5a that protrudes from its end face, a plate 6, into which a piezoelectric resonator 7 is integrated, an impedance transformer 9, an internal microphone line 8 and a cable 10 that extends outward. The elements 1-10 which are shown in Figure 1 have an interdependence that pertains to the transmission process itself as well as to all measures for increasing the transmission quality. The diaphragm 5 is designed in such a way that the resonance generated by the body vibrations is transmitted onto the plate 6 that is functionally

connected to the pin 5a and to the resonator 7 with the highest possible degree of efficiency. For example, one negative aspect in this context would be the use of a diaphragm 5 that, in particular, due to its physical properties, is unable to transmit the small portions of high frequency sounds or would have the characteristic of suppressing these frequency sounds. The surface of the diaphragm 5 which is situated on the side of the body is preferably coated with a precious metal in order to increase its skin compatibility. The diaphragm 5 is functionally connected to the plate 6 via the pin 5a, with this connection preferably being produced by means of a partial contact. The plate 6 may also contain a centering depression for the pin 5a such that the assembly of these parts is subjected to a quality assurance. This centering between the pin 5a and the plate 6 may also be achieved by connecting the pin 5a to the plate 6 by means of hard soldering. This configuration provides the advantage that the entire diaphragm 5 is not physically impeded relative to the outer housing 1, i.e., absolutely free-vibrating. This has positive effects on the degree of efficiency of the transmission of structure-borne vibrations onto the plate 6 because a direct transmission predominates. The plate 6 is embedded in the intermediate ring 4, with the mutual fixing between these two parts being discussed in detail below with reference to Figure 2. Consequently, the vibrations that are picked up by the diaphragm 5 act upon the plate 6 and the piezoelectric resonator 7 integrated centrally therein. The integration of the piezoelectric resonator 7 into the plate 6 needs to be carried out in such a way that the centers of gravity of both elements coincide with one another. Due to this measure, it is ensured that the resonator 7 is also only activated in a punctiform fashion. The intermediate ring 4 that serves as the carrier for the plate 6 and the resonator 7 is embedded into the insulation body 3 in such a way that the piezoelectric resonator 7 is, except for the surface on the side of the diaphragm, insulated from ambient noise on all sides. The damping or insulating material may, for example, consist of a silicone mass that is introduced into the free space between the outer surface of the intermediate ring 4 and the inner surface of the outer housing 1. The impedance transformer 9 is integrated into the amplifier 2, with the impedance transformer being connected to the piezoelectric resonator 7 via the line 8. The two latter-mentioned elements contribute to an increase in the quality of the transmission of the voiced sounds by capturing structure-born vibrations. The impedance transformer 9 carries out an impedance adaptation to a radio unit which is connected to the microphone that responds to structure-borne sound via the cable 10. The material of the plate 6 needs to be chosen such that it has a low capacity to absorb vibrations. This can be achieved with a conventional spring steel. Due to this measure, the vibration amplitudes of the piezoelectric resonator 7 that cooperates with the plate 6 can be influenced in such a way that a superior resonance which leads to an improvement in the reproduction quality of the voiced sounds is achieved. Additional provisions regarding this purpose pertain to the design of the plate 6 which is described in greater detail with reference to Figure 2. Since the vibrations on the side

of the body which are initiated by the voiced sounds have a nearly punctiform concentration on the diaphragm 5 and the pin 5a, and since this punctiform concentration triggers a maximized effect on the piezoelectric resonator 7, the plate 6 needs to have a minimum thickness if its resistance should be able to provide the bending elasticity required for this purpose. The minimum thickness of the plate 6 is also defined by the fact that the entire microphone has a diameter of only 10 mm, i.e., the plate 6 has a diameter of only 6-7 mm.

Instead of using a piezoelectric resonator 7, one embodiment of the invention which is not illustrated in the figures utilizes an induction element that preferably consists of a coil and a magnet core as the transmitter. This element is connected in series to the plate 6 at a certain distance. The coil and the magnet core form a so-called dynamic transmitter that does not require the voltage which is absolutely imperative for a piezoelectric resonator ("phantom feed"). In this case, the transmission takes place due to the induction generated by the transmitter in dependence on the vibrations that originate from the plate 6 due to the fact that the diaphragm 5 on the side of the body acts upon said plate. Such a variation is particularly suitable for instances in which no voltage for feeding the piezoelectric resonator 7 is available, e.g., for units used by pilots.

Figure 2 shows a section along the plane II-II in Figure 1. This figure shows the type of anchoring and the geometric shape of the plate 6. The plate has a round shape and is connected to the inner wall of the intermediate ring 4 at three points 6a, 6b, 6c. If one connects these three fixing points to one another with an imaginary line, an equilateral triangle is formed. This configuration is responsible for the uniformity regarding the nodal lines of the acoustic pattern, i.e., an acoustic pattern that is trimmed to harmonics and in which the high frequency sounds are transmitted in a preferred fashion results. Naturally, other ways of fixing the plate may be chosen and used for correcting the remaining variables of the respective plate used. Recesses 6d, 6e, 6f in the plate 6 are assigned to each fixing point 6a, 6b, 6c, with said recesses also describing a uniform progression from a geometric point of view. These recesses 6d, 6e, 6f form another effective option for influencing the physical properties of the respective plate 6. The recesses 6d, 6e, 6f alter the excitability of the plate 6 in such a way that an excessively high resonance of the plate 6, the progression cumulation of the frequency response of which would exceed the optimal 3000 Hz, is reduced. In order to prevent the anchoring branches 6g, 6h, 6i of the plate 6 from becoming excessively weak, the recesses 6d, 6e, 6f are, if the resonance needs to be additionally reduced, extended such that they are angled toward the interior of the plate 6. In this context, it needs to be observed that the plate 6 has the largest possible free surface within the region of the piezoelectric resonator 7. Another variable of the plate 6 is the width of the recesses 6d, 6e, 6f. This width needs to be adapted to the respective requirements regarding the desired frequency response. Vibrations which impact the fixing points 6a, 6b, 6c horizontally or quasihorizontally are unable to propagate into the interior up to the piezoelectric resonator 7 due to the rigidity

gradient which results with respect to the plane of the plate 6, upon which the vibrations act. Generally speaking, these vibrations are reflected and primarily absorbed by the insulation body 3. The only path available for vibrations of high energy is a surface propagation along the end faces of the plate 6, namely from one fixing point to the remaining fixing points. The mutual neutralization of the vibrations which travel from one point to the other points becomes more effective with the accuracy of the equilateral triangular shape of the fixing points 6a, 6b, 6c. Consequently, the chosen three-point anchoring of the plate 6 in the geometry of an equilateral triangle provides advantages in two respects. In addition, a slight surface roughness of the entire plate 6 has energy-consuming effects upon these vibrations. The vicinity of the maximal activation point of the piezoelectric resonator 7 consequently is never subjected to vibrations from ambient noise.

Vibrations which are incident on the microphone via another plane are neutralized by the insulation body 3 anyhow. The compactness of the entire microphone which only has a height of approximately 8 mm consequently makes the adjustment for self-vibrations possible. The only plane that is "permeable to vibrations" is the plane on the side of the diaphragm which adjoins the body. This is the reason why only structure-borne vibrations are able to act upon the microphone, i.e., the piezoelectric resonator or the induction element, respectively.

Figure 3 shows one possible utilization of the microphone according to Figures 1 and 2, with the reproducing/recording unit shown in this figure simultaneously aiming to eliminate the disadvantages of known units of this type.

One known unit that can be worn on the ear consists of a kidney-shaped strap that is bent at a right angle on the side of the head and connected to the carrying part of the reproducing and recording capsule. The opening of this strap is smaller than the average size of a human ear. It was determined that the attachment of this unit is not satisfactory because it is necessary to force the ear through the kidney-shaped opening each time the unit is attached. In addition, the bending of the strap at a right angle relative to the reproducing/recording surface is not ideal for all shapes of ears: with protruding ears, the unit will hang loosely and nonpositioned; with ears that flatly adjoin the head, pressure points will inevitably result in pain. However, it is not only the attachment of the unit which is unsatisfactory with respect to ergonomic and comfort considerations, but the removal also proves to be uncomfortable. This is compensated by applying excessive force which may lead to a painful deformation of the ear. In such a unit with a closed ear strap, the potential of injuries to the ear is always present, e.g., if the unit is connected to a rigid connection point via a cable and the unit is not removed when the person leaves the respective location such that the unit dangerously and painfully pulls on the ear.

The situation is quite different with the proposed unit, the strap 11 which is able to optimally adapt to any ear shape without producing any pressure points on the ear. This is

achieved by providing the ear strap 11 with a degree of resilience in at least one spatial plane, i.e., the ear strap 11 is elastically movable relative to a reproducing/recording insert 12. The degree of resilience of the ear strap 11 is indicated in Figure 3. In the idle condition, this ear strap 11 is bent up to approximately the center of the reproducing/recording insert 12 by a spring part 11b that acts at the beginning of the ear strap 11 as indicated by the position 11a of the ear strap 11. This means that the spring part 11b is bent at a right angle relative to the inner surface of the insert 12 on the side of the ear, namely such that the tension of the unit being worn is defined by the elastic bending force of the spring part 11b, i.e., a second plane of resilience of the ear strap 11 becomes effective. The bending distance of the unit being worn is a measure between the inner surface of the insert 12 on the side of the ear and the position of the ear strap 11 which corresponds to the difference in height between the ear inlet, at which the reproducing capsule 13 this positioned, the temporal bone region which the microphone adjoins and the back of the ear which the strap 11 adjoins and simultaneously ensures the required stability for the entire unit. The flexibility of the ear strap 11, which may be simply achieved with the spring part 11b shown or a uniformly elastic strap, makes it possible to attach and remove the unit in a much simpler fashion. A uniformly flexible ear strap is able to deform and adapt quite easily depending on the respective contour of the back of the ear. This has positive effects on the position of the reproducing capsule 13 and the microphone 1-10 because they assume their assigned positions in which they operate optimally. Naturally, the ear strap 11 may contain another right-angled bend 11c that increases the comfort and rises from the ear strap 11 on the side of the cranium. In this case, the right-angled bend 11c may only be provided in the lower section of the ear strap 11, with the remaining section of the ear strap 11 maintaining the original progression up to the insert 12. The cable 14 to a connecting point extends within the ear strap, i.e., the tension of the entire unit is alleviated when it is worn and no interfering effect upon the front side of the face results.

The cable 14 preferably extends helically such that it is able to extend between various differences between the ear and the connection point without causing interferences.

Figure 4 shows a unit 12a that only contains a reproducing capsule, with this design of the ear strap 11 corresponding to the embodiment described previously with reference to Figure 3.

Naturally, the microphone 1-10 according to the invention may also be integrated into any other reproducing/recording or recording unit. This pertains, in particular, to reproducing/recording units that pick up voiced sounds at the throat.

Claims

1. Microphone which responds to structure-borne sound, with said microphone essentially consisting of a microphone capsule, a sound pick-up on the side of the body and a transmitter

that is connected in series to this sound pick-up and operates with or without an amplifier/impedance transformer, and a plate as well as a piezoelectric resonator integrated therein, with the sound pick-up on the side of the body being functionally connected to the plate and the piezoelectric resonator integrated therein, and with the plate being directly or indirectly connected to the microphone capsule at various discrete locations and containing recesses near the connecting points, characterized by the fact that the connection between the plate (6) in the microphone capsule (1) consists of a three-point anchoring, the three fixing points (6a, 6b, 6c) of which form the corners of an equilateral triangle, with at least one recess (6d, 6e, 6f) in the plate respectively being assigned to each of these three fixing points.

2. Microphone which responds to structure-borne sound, essentially consisting of a microphone capsule, a sound pick-up on the side of the body and a transmitter that is connected in series to this sound pick-up and consists of a plate as well as an induction element mounted thereon, with the sound pick-up being functionally connected to the plate and the induction element mounted thereon, and with the plate being connected to the microphone capsule, characterized by the fact that the connection between the plate (6) and the microphone capsule (1) consists of a three-point anchoring, the three fixing points (6a, 6b, 6c) of which form the corners of an equilateral triangle, with at least one recess (6d, 6e, 6f) in the plate being respectively assigned to each of these three fixing points.

3. Microphone according to Claim 1, characterized by the fact that the centers of gravity of the plate (6) and the piezoelectric resonator (7) coincide with one another.

4. Microphone according to Claim 1, 2 or 3, characterized by the fact that the sound pick-up (5) on the side of the body directly acts upon the center of gravity of the plate (6) via a pin (5a).

5. Microphone according to Claim 1 or 2, characterized by the fact that the plate (6) consists of a bronze alloy.

6. Microphone according to Claim 1 or 2, characterized by the fact that the recesses (6d, 6e, 6f) respectively have the same progression with reference to the respectively assigned fixing points (6a, 6b, 6c).

7. Microphone according to Claim 1 or 2, characterized by the fact that the recesses (6d, 6e, 6f) contain at least one angled section which is directed toward the center of the plate (6) as their distance from the edges of the plate (6) increases.

8. Utilization of microphones according to one of Claims 1-7 in reproducing/recording units or recording units, in which the pick-up of voiced sounds takes place within the region of the throat and/or another location of the body that is made for picking up voiced sounds.